RTT TECHNOLOGY TOPIC
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Guided media - where next?

It is a 5G marketing conceit that at least part of the 5G added value proposition will be based on providing mobile wide area wireless broadband (unguided media) connectivity with similar performance to fixed guided media (copper, cable and fibre).

This is based on being able to achieve headline data rates and per bit delivery costs that are comparable to existing fixed line (guided media) service offers.

What this fails to comprehend is that all three guided media options are benefiting from a level of technology innovation that is at least equal to mobile broadband technology innovation. This suggests that the performance gap between mobile broadband and fixed connectivity will remain at best constant and may in practice widen.

It is not just data rates but bit quality. Error rates in fibre as an example are specified at 1 in 10^{12} compared with 1 in 10^{3} for legacy cellular networks. Channel conditions in guided media are relatively stable. Channel conditions in wide area wireless are constantly changing.

Cellular networks have traditionally reduced net error rate and the impact of fading by channel coding and using send again protocols but this introduces delay and delay variability which means a number of potential vertical market applications become harder to address.

Many of the technology advances in guided media including present copper upgrades will have a beneficial impact on Wi-Fi performance but relatively less positive impact on wide area cellular.

The only way in which wide area 5G can play catch up with fixed guided media and maintain an acceptably comparable performance to local area Wi-Fi is to emulate guided media physical performance more closely.

This can only be achieved by using narrow beam widths combined with efficient bandwidth ratios both of which are more efficiently achieved at shorter wavelengths in the centimetre and millimetre bands.

Read on

Guided media development

The guided media story is in practice not that different to wireless in that throughput is determined by frequency, bandwidth and propagation loss (or dispersion loss in fibre) and efficient use of power.

Fast Copper

For Fast copper, the major objective is to breathe new life into legacy twisted pair in the local loop serving domestic and business premises up to 500 metres from the fibre cabinet. Existing VDSL2, using frequencies up to 17 MHz or 30 MHz, is being replaced by G.fast working up to 106 MHz or 212 MHz to support data rates of between 150 mbps and 1 Gbps. Cross talk increases at higher frequencies and has to be managed by implementing noise cancellation.

Fast Cable

The **D**ata **o**ver **C**able **S**ervice **I**nterface **S**pecification (DOCSIS) standard for broadband cable was introduced in 2008 with the fifth generation (DOCSIS 3.1) introduced in 2013. The standard has to be compatible with US and European terrestrial channel bandwidths (6 MHz and 8 MHz) and Australian channel bandwidths (7 MHz).

DOCSIS 3.1 has LDPC error correction, OFDM and anything between 256 QAM and 8192 QAM modulation though 8192 QAM needs a signal to noise ratio of 44 dB which makes its use largely theoretical. Sometimes described as the G-fast of cable, channel bandwidths are up to 192 MHz downstream and 96 MHz upstream. DOCSIS 1 works at frequencies up to 1002 MHz; DOCSIS 2 extends this to 1218 MHz and DOCSIS 3 to 1794 MHz. DOCSIS 3.1 achieves transmission rates of up to 10 Gbps downstream and 1 Gbps upstream. Nokia Bell Labs have recently announced successful 10 gbps symmetrical transmission over 100 metre cable lengths.

Fast Fibre

Fibre systems up to 10 Gbps have historically used direct detection with a photo detector that responds to changes in the received signal optical power. No phase or frequency information is extracted from the optical carrier.

Fast or rather faster fibre uses coherent detection where an optical receiver tracks the phase and frequency information carried by the transmitted signal. In a coherent detector, a narrow line width tuneable laser acts as a local oscillator to mix with the received signal to recover the amplitude and phase information on the optical carrier.

The result is improved sensitivity and increased capacity and the ability to use digital signal processing to compensate for chromatic and polarization dispersion in the fibre, reducing or eliminating the need for optical dispersion compensators and their associated optical amplifiers. As laser phase noise reduces, these system benefits become progressively more realisable.

Coherent detection is used in long haul optical networks and is becoming more common in metro optical networks and is the basis for present industry ambitions to scale from existing 40 Gbps (40G) systems to 100 and 400G producing a step function improvement in throughput and reduced cost per bit (lower capital and operational costs).

How Wi-Fi benefits more from improved guided media performance

While it could be argued that improved guided media performance benefits cellular and Wi-Fi equally there is a counter argument suggesting that the practical impact on Wi-Fi will be more significant. This is because cellular is usually constrained by link budget and RF interference rather than backhaul congestion whereas Wi-Fi is more prone to be affected by contention in the local loop where G.fast in particular could potentially make a major difference.

Wide area cellular – the beam width and bandwidth and linearity implications

The comparison is of course unfair as wide area cellular has additional physical layer overheads to deal with mobility and a need to accommodate 30 to 40 dB of additional dynamic range over and above a Wi-Fi connection.

That aside it is quite possible to improve cellular throughput efficiency to the point where it is at least perceptually similar to wireline or Wi-Fi connectivity but this depends on using narrow beam width antennas in the base station and handset to improve the bi directional link budget. A one degree beam width antenna should theoretically realise over 40 dB of isotropic gain.

However making the beam adaptively steerable requires multiple phase array antennas which need to have adequate physical (wavelength) separation. This is only practical in user devices at centimetre and millimetre wavelengths.

Additionally there is a need to maintain highly linear phase off sets between each of the antenna elements. Maintaining sufficient linearity becomes harder at higher bandwidth ratios, for example greater than 10% of centre frequency. Matching also becomes less efficient. By implication this means that if 500 MHz of channel bandwidth is needed to deliver a high bit rate connection then the centre frequency needs to be at 50 GHz. 750 MHz of channel bandwidth needs a centre frequency of 75 GHz.

Beam width and bandwidth are both a proxy for power. A narrow beam concentrates RF energy where it is needed. Bandwidth ratios of 10% or less allow for optimum RF matching and improved linearity. The end outcome is better RF efficiency. This translates into higher throughput, lower energy per bit and a better end user experience.

Summary

The marketing ambition is that 5G should be capable of delivering a mobile wide area high bit rate connection experience that is perceptually equivalent to fixed line or Wi-Fi connectivity both of which are continuously improving in terms of throughput, bit quality (lower noise floors) and per bit delivery cost.

A cost and performance competitive service offer from 5G is plausible but will be dependent on having the right sort of bandwidth and bandwidth ratio to support the required linearity needed to deliver efficient and effective adaptive beam forming. By default this suggests the centimetre and millimetre bands are going to be the most economic option for high bit rate wide area 5G networks.

Wireless has significantly more bandwidth available than either cable or copper. It is power that is the problem with power efficiency (rather than spectral efficiency) being a critical 5G performance parameter – a topic which we address in detail in our next three technology topics.

Ends

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